DEFENCE R&D DÉFENSE

1997 Canadian Forces Air Operations Vision Survey

Sections III, IV, V and VI
Vision protectors and enhancers

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Defence R&D Canada

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EXECUTIVE SUMMARY

A thorough knowledge of the use and limitations of vision protectors (sunglasses, clear and sun visors and laser protective devices –LPDs) and vision enhancers (especially Night Vision Goggles -NVGs) is important to flight safety.

In 1997, DCIEM conducted an Air Operation Vision Survey to gather information from Canadian Forces (CF) pilots regarding their usage, understanding and appreciation of current vision protectors and enhancers. This third and final report relates demographics, training and operational effectiveness, to the use of sunglasses, clear and sun visors, LPDs and NVGs in the CF.

Sunglasses are preferred by rotary wing (RW) pilots which include Tactical Helicopter (TH), Search & Rescue (S&R), and Maritime Patrol (MPRW) and fixed wing multiple crew pilots (FWMC) which include Transport (TSPT) and Maritime Patrol (MPFW) aircraft. Personal sunglasses are preferred to CF issued sunglasses by most aircrew except for fighter pilots. Sunglasses used for flying duties, issued and otherwise acquired, span a wide range of coloured lenses and optical features.

Clear visors are mainly used in day time by Single Crew Fixed Wing (SCFW) pilots and are widely accepted for night operations in the SCFW and RW communities. Some pilots are reluctant to use clear visors at night, fearing decreased visual acuity, loss of contrast sensitivity and glare. Sun visors are used mainly by RW pilots and SCFW pilots. Unlike SCFW pilots, RW pilots use this visor in combination with sunglasses. The current CF sun visor is not judged acceptable under all flying conditions, occasionally being judged too dark or too light, depending on flying conditions.

Up to 1997, LPDs had been used by only a small fraction of the CF pilot population generally in the fighter (FGT), MPRW and TH environments. Level of experience with these devices was generally low (16-20 hrs) and no pilot reported any laser in-flight incidents. Most pilots had not received any aeromedical training regarding these devices nor were all of them aware of the operational limitations associated with specific LPDs. Training with these devices was somewhat informal and usage in training or operational settings was not universal.

NVGs usage was mainly restricted to the TH environment and the average experience level in 1997 was between 16-50hrs of flight time. Although the training was rated as "acceptable", serious shortcomings regarding adjustment procedures and knowledge of technical and operational limitations of the device were revealed.

The 1997 CF Air Operations Vision Survey provides a useful outline of the distribution and characteristics of vision protectors used by CF pilots. It indicates the need to review the operational relevance of current CF sunglasses and sun visors and demonstrates deficiencies in training and the knowledge of the limitations of LPDs and NVGs. This survey provides important information to those involved in the provision of and training with these visual enhancers and protectors

ABSTRACT
Introduction: In 1997, DCIEM conducted an Operational Vision Survey of current Canadian Forces (CF) pilots. This third report deals with those aspects related to vision protective and enhancement equipment, specifically sunglasses, visors, laser protective devices, and night vision goggles. **Results:** 1551 questionnaires were sent out. 813 questionnaires were completed and 200 returned "undelivered" for a response rate of 60% of those actually received. Regarding the preference of specific vision protectors, significant differences were noted between Rotary Wing (RW), Single Crew Fixed Wing (SCFW) and Multiple Crew Fixed Wing (MCFW) pilots. Sunglasses were preferred by MCFW pilots, sun visors in combination with sunglasses by RW pilots, and clear visor by SCFW pilots. The tint of the current sun visor is not universally well received and is considered as either too dark or too light for specific operations. Clear visor are used at night mainly by RW and SCFW pilots but some pilots are still reluctant to use it for fear of inducing distortion and glare. Laser Protective Devices (LPDs) are used sporadically even when a laser threat may exist. Understanding of the limitations of LPDs when viewing inside and outside the cockpit is insufficient. Night Vision Goggles (NVGs) were mainly used by Tactical Helicopter (TH) pilots. The need for better training and knowledge of the visual and operational limitations of these devices was identified. **Conclusions:** The survey is a useful tool in outlining the distribution and characteristics of vision protectors used by CF pilots. It indicates the need to review the operational relevance of current CF sunglasses and sun visors and demonstrates problems with training and knowledge of the limitations of LPDs and NVGs. The results from the survey provide useful information on current visual aids and protectors.

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INTRODUCTION

Personal vision equipment for aircrew is meant to protect and enhance vision in the operational setting. However, while affording protection, visual protective devices (including sun glasses, clear and tinted visors, and laser protective devices - LPDs) may compromise visual function, for example by introducing colour changes and distortion. Similarly, while enhancing night vision, Night Vision Goggles (NVGs) also introduce complex visual problems including a new visual frame of reference, and visual illusions.

To evaluate the perceived effectiveness amongst the pilot population of current Canadian Forces (CF) aircrew visual protective equipment including sunglasses, visors and NVGs, the 1997 Pilot Vision Survey included questions related to equipment for visual protection and enhancement. Questions addressed the following topics:

Vision protectors:

- Characteristics of CF-issued and personal sunglasses used for flying duties;
- Use of CF clear and sun visors;
- Acceptability of CF visors for day and night operations;
- Demographics regarding the use of LPDs
- Aircrew understanding with respect to the limitations of LPDs and related training issues;
- Visual problems related to the use or omission of using LPDs; and
- Operational problems regarding LPDs

Vision enhancers:

- Demographics with respect to the use of NVGs;
- Training issues;
- Adjustment issues
- Visual problems related to the use of NVGs; and
- Demographics of NVG incident occurrences related to human factors and/or equipment malfunction.

METHODS

In May 1997, 1551 questionnaires were sent to all regular and reserve CF pilots listed within National Defence Headquarters (NDHQ) as of April 1997. Accompanying the survey were letters from the Commander of Air Command and the Director of Flight Safety emphasizing the importance of this study and encouraging pilots to provide personal input and experience. All nine main operational roles were canvassed: Tactical Helicopter (TH), Search & Rescue Rotary Wing (S&RRW), Maritime Patrol Rotary Wing (MPRW), Maritime Patrol Fixed Wing (MPFW), Transport (TSPT), Fighter (FGT), Jet Trainer (JTR), Primary Trainer Fixed Wing (PTFW) and Primary Trainer Rotary Wing (PTRW). Four months were allocated to complete and return the survey to DCIEM.

Questions regarding vision protectors and vision enhancers were of three types: yes/no answers, choice of answers with the possibility of a written comment, and rated answers on acceptability achieved through the following 5-point scales:

	Rating value				
	1	2	3	4	5
Acceptability	wholly unacceptable	unacceptable	borderline	acceptable	wholly acceptable

STATISTICAL ANALYSIS

No specific statistics were used to analyse the results of these three sections with the exception of contingency tables (CT) in specific cases to determine whether a relationship existed between the variable "airframe type" and the answers provided.

RESULTS/ DISCUSSION AND COMMENTS

A. Survey demographics

By October 1997, 813 questionnaires were completed and returned to DCIEM from the initial 1551 sent out. Sixty-four (64) questionnaires were returned indicating "released from the CF" and 136 designated as "posted", "unknown", or "no return address". The overall return rate of mailed questionnaires for this voluntary CF survey was 56%; for the 1331 pilots who actually received the survey the return rate was 60%.

B. Vision Protectors

a. Sunglasses

(1) Demographics

The survey results disclosed that sunglasses are used for flying duties by 56% of CF pilots. MCFW pilots are the largest user-group, with 89% usage, a significantly higher rate (chi square p-value < 0.0001) than TH (44%) and SCFW (31%) pilot populations.

Overall, pilots preferred personal sunglasses to CF issue sunglasses (62% vs 38%). Of the pilot population using sunglasses for flying duties, 32% wear prescription sunglasses. For prescription sunglasses, CF issue was more common (62%) than personal sunglasses (38%). There is no significant difference between airframe for use of corrective sunglasses (chi-square p-value 0.4). Table 1 presents an overview of the demographics of sunglass use amongst the responding pilots.

(2) Characteristics of the sunglasses

CF issued or personal sunglasses were generally described as grey or green. However brown, amber, blue and smoky pink also used by pilots for flying duties. Generally speaking CF pilots considered the tint of current CF sunglasses acceptable regardless of the colour of their lenses or the airframe type (chi square p-value 0.6).

Twenty-six percent of pilots wearing sunglasses had polarised lenses. These lenses are encountered both in personal and CF issued sunglasses. TSPT, TH and MPFW are the operational roles in which these sunglasses were most commonly utilized. Seven percent of pilots had gradient tint sunglasses for flying duties. Although the majority of gradient tint lenses are found in personal sunglasses, there were also some issued as CF sunglasses. Table 2 presents an overview of the characteristics of both CF-issued and personal sunglasses used by the pilots.

Comments / Discussion: Overall, sunglasses are utilized by a majority of CF pilots (56%). Not surprisingly, sunglass utilization is highest in those operations not requiring a helmet i.e. TSPT and MPFW aircrew.

Despite the guidelines for aircrew sunglasses outlined in CFMO 6-51, the survey highlights a signficant lack of standardization of aircrew sunglasses, with a wide range of colours and optical characteristics. Some of these off-nominal features, such as colour variations (including amber, blue or smoky pink), and optical characteristics (such as gradient tint) have the potential for a significant flight safetly impact.

This lack of standardization for sunglasses is not entirely surprising. Previous research done by the US Navy demonstrated a similar tendency. Hamilton and Morris (1986) showed that US Navy pilots' sunglasses included amber fixed density sunglasses, amber photosensitive sunglasses, variable density sunglasses in addition to the sun visor and even in one case a personal gold visor. The selection of sunglasses seems to involve subjective factors such as squadron policy, peer opinions, or personal feeling of comfort.. There seems to be no objective or systematic basis amongst pilots for finding the "right" sun visor or sunglasses, and pilots use a trial/error selection process until such time as they feel they have found what seems best suited to their needs (Hamilton & Morris , 1986). The wide range of sunglasses encountered amongst US Navy pilots and now documented within the CF pilot community may reflect dissatisfaction with currently available CF issued sunglasses and the lack of objectivity in developing a standard policy regarding sun protective eyewear.

b. AIRCREW VISORS – Clear and Sun Visors

The majority (68%) of CF pilots indicated that they use both clear and sun visors, with an obvious operational difference between RW/FWSC and FWMC (87% vs 28% - see Table 3).

There was a mixed use of visors both with and without sunglasses (see Table 5). The most prevalent use was of the clear visor without sunglasses for day operations, most commonly by RW and FWSC pilots. RW pilots also frequently chose to wear sunglasses both under a clear visor, or under the sun visor significantly more often than other pilot groups (chi-square $p<0.02$). There were 387 pilots (47% of the population surveyed) who used the clear visor for night operations – with no significant differences amongst airframes. Of those not using the clear visor for night operations, reasons given included glare, distortion, a perception of decreased visual acuity and decreased contrast (see Table 4 for a tabulation of reasons for not using the clear visor for night operations).

Sun visors without sunglasses were used most often by FWSC pilots, while the combination of sunglasses under clear visors were utilized most commonly by RW pilots (chi-square $p<0.0001$).

Pilot opinion was sought on the current neutral grey tint for the sun visor, and 526 pilots provided feedback. RW and FWSC pilots indicated the most problems with the tint, reporting that the visor is too dark when flying away from the sun and too light for winter operations, and when flying towards the sun. FWSC pilots also reported the visor as being too light for high alititude operations. In these situations, there was a significant trend to use a combination of sunglasses and sun visor. Table 6 summarizes the concerns reagarding the tint of the sun visor, as grouped by the type of operational flying.

Comments/Discussion: The preference for the clear visor amongst fighter pilots may lie in the perception of decreased acuity when filters are interposed (sun visor or sunglasses), especially at altitude. The association of low transmittance of MILSPECS filters –visors and sunglasses –with difficulty acquiring low contrast targets under high illumination has been verified by Hamilton and Morris (1986).

That the CF current visor is not optimal for all daylight conditons is similar to reports from United States Air Force (USAF) and United States Navy (USN) studies (Hamilton and Morris, 1986; Task 1989; Young 1999). US Navy sunglasses have a MILSPEC of 12% transmittance (instituted over 35 years ago), and the MILSPEC for US Air Force and Army sunglasses is for $15 \pm 3\%$ transmittance. Both are generally perceived as

too dark for most air operations (Brennan, 1989). The origin of these specifications is not clearly known but is thought to have been based on recommendations made by Farnsworth over 40 years ago for working requirements for "ship crew" sunglasses (Hamilton and Morris, 1986). It has been recommended that the transmittance level for aircrew sun visors be increased to levels between 25-30% (Task, 1989), and more recently to 49% (Young et al, 1999) to improve low contrast visual acuity and colour perception. Since it is recognized that the current sun visor may be inappropriate for current flight operations, the choice of a new transmittance level should be based on operational data derived from the most common operational situations, including high altitude flight, and low-level flight including that over water and snow.

Concerns about using clear visors including perceptions of increased glare and decreased visual acuity have also been corroborated by laboratory research. The induction of veiling glare caused at night by the scattering and/or reflection of light on a scratched or pitted clear visor and canopy is a well known phenomenon (Clark, 1989). Ginsburg (1983) with a Heads Up Display (HUD) and Hughes and Vingrys (1991) with windshield trials showed reduced contrast sensitivity in pilots under these conditions. This reduction is positively correlated with aircraft recognition distances (Hughes & Vingrys, 1991). The combination of increased glare and decreased contrast sensitivity when viewing through a windscreen in day time condition has been shown to lead to an decrease in target detection range up to 20% (Hughes and Vingrys, 1991).

c. Laser Protection Devices (LPDs)

Only 29 pilots of the 813 total survey respondents completed the section pertaining to (LPDs). Their operational flying roles included FGT (10), MPRW (9), TH (5), MPFW (1) and TSPT (1) aircraft. The majority (17) indicated that they had less than 10 hours experience with LPDs. Seventeen of the 29 LPD respondents indicated they always used an LPD during exercises involving lasers. None of the 29 reported any laser exposure, nor any incident/accident involving flash blindness or visual disturbance in flight related to either commercial or military lasers. However, in Section 2 of the Aircrew Vision Survey related to Clinical Support, one pilot indicated having been grounded after a laser incident.

The following LPDs had been or were in use in the CF at the time of the survey.

- Gentex 1-band (amber)
- Gentex 2-band (green)
- Army 3-band (brown spectacles)
- EEK
- Barnes (pink day-time only)
- FV-2 (amber day-time only)
- FV- 4 (dark amber day-time only)

Of the 29 pilots reporting experience with LPDs, 10 were not able to specify which of the LPDs they had used. Only 13 of the 29 had received aeromedical information about the LPDs. Five pilots indicated they had not been briefed on how lasers can damage eyes. All 29 were aware that a single LPD did not provide protection against all lasers used in military operations. Nine indicated they had flown with day-only LPDs during night operations.

With respect to the usefulness of training with LPDs, there was a wide range of responses from "wholly unimportant" (2), "unimportant" (11), "borderline importance" (5) and "important" (9)

Of the visual problems associated with LPD use, 37% of the pilots reported eye fatigue. Other symptoms reported included headaches, mental fatigue, eye redness, and blurred vision. These symptoms were apparently rarely mentioned to the Flight Surgeon.

Perception Issues:

Pilots with experience on the LPDs most commonly utilized in the CF (Gentex 1 and 2 band visors) were asked to rate the acceptability of various visual elements such as aircraft position lights, aircraft colours, tarmac lights, instrument displays, and Light Emitting Diodes (LED) buttons. Thirteen pilots provided input for the 1 band visors, and 6 for the 2 band visors. On average, perception for the various visual elements was rated as "acceptable". Pilots using 1-band visors reported as "borderline" the perception of red aircraft position lights, and tactical blue aircraft. For the 2-band visors, perception of green LED buttons and HUD symbology was rated as "borderline".

Comments/Discussion: At the time of the survey, LPD usage was restricted to FGT and MPRW operations, and to a lesser extent TH operations. The level of experience in the CF with LPDs was very limited. Despite this limited experience, training issues emerged as important, with less than 50% of those having flown with LPDs reporting having received aeromedical training related to LPDs. Of those, 35% indicated that they did not know what type of LPD they had flown with and 31% indicated that they had flown with day-only LPDs during night operations, none of whom had had an aeromedical briefing.

There are many visual issues associated with LPD use, as outlined by Thomas (1994). Pilots using LPDs should be made aware of and be fully briefed on these issues, which include:

Out-of cockpit viewing:

- Blending of surface colour and loss of terrain features;
- Reduced Tally-ho ranges;
- Loss of depth perception;
- Excessive sun and glare from inadequate protection; and
- Problems seeing exterior aircraft lights.

In-cockpit viewing

- Problems seeing warning, caution and advisory lights;
- Problems seeing HUD and monochromatic Head Down Dispays (HDDs);
- Problems seeing colours and geographical features on aviation maps;
- Problems seeing warning, caution and advisory lights;

Transitioning from Outside to inside cockpit viewing

- Time required to adjust to change in brightness condition.

The colour perception problems regarding tactical green, blue, and grey aircraft, and red aircraft position lights with the 1-band (amber) LPD are consistent with previous reports assessing colour confusion with yellow/amber lenses by Kuyk and Thomas (1988) and problems of seeing red aircraft position lights by USAF pilots (Sulak, 1988 and Report from USAF HQ TAC, 1991). The problems of seeing standard dial instruments and red and amber LED buttons with the 2-band (blue-green) LPD has also been reported by Thomas (1994). Problems with colour perception are magnified for CV2 (colour deficient safe) pilots (Heikens, 1997)

As these problems may vary from one LPD to another, specific briefing notes should be made available regarding the characteristics of each LPD and potential problems associated with their use. These should be distributed to each squadron using LPDs for briefings before each mission in which LPDs will be used.

C. Vision Enhancers – Night Vision Goggles (NVGs)

(1) Demographics (Table 6)

185 pilots responded to the section pertaining to NVGs. Of these, 71% were TH pilots. The remaining 29% included pilots in S&R, MPRW, TSPT, FGT, PTFW and PTRW operations. The average experience level was from 16-50 hours of flight time.

(2) Sources of NVG instruction

A total of 93% of NVG instruction was provided by NVG-qualified instructor pilots. Respondents also reported receiving instruction from aeromedical technicians, flight surgeons, other line pilots, and company representatives. Table 7 gives a breakdown of the sources of instruction, and Table 8 an overview of the topics covered.

(3) Vision Problems reported with NVGs

Table 9 provides a list of visual problems reported by the pilots flying with NVGs. The main problems reported were eye strain (75%), excessive fatigue (60%) and headache (52%). Additionally, 33% reported that their vision was changing, either improving or degrading during the course of an NVG mission.

Comments/Discussion: The problems reported by CF pilots using NVGs are similar to those reported by USAF and US Army pilots (Crowley, 1991). Crowley showed that problems related to eye-strain, headache and blurred vision can be minimized by proper adjustment of the NVGs (see next section).

(4) Adjustment and operational limitations

There were 19% of pilots who indicated that they had encountered problems when trying to align their visual axis with the optical axis of the NVGs. Tilt and intrapupillary distance (IPD) adjustments were rated on average as "acceptable" while the eye relief and vertical adjustments were rated as "borderline". For all types of adjustments, there was no difference reported by pilots wearing corrective spectacles compared with those without spectacles.

Only 48% of the pilots reported their unit had an NVG adjustment lane, and only 32% reported using the lane. Reasons given for not using the adjustment lane included the lack of a standardized protocol (57%), excessive time required for the adjustment process (36%), and/or that the lane was not conveniently located (22%). For pilots not using the adjustment lane by choice, or because it was not available at their squadron, various methods of adjustment were used. These are summarized in Table 10, and included focussing on a static aircraft or vehicle (52%), on a distant building (44%), or on an artificial light source (35%).

Many pilots reported refocusing their NVGs during the actual mission. Pilots reported refocusing immediately after take off, automatically after a certain elapsed time, before specific manoeuvers such as landing in a confined area, doing target identification, or when environmental visual changes occurred due to illumination level or weather. These are summarized in Table 11. NVG adjustments made during flight included setting the objective only (37%), the diopter only (6%), or both (55%).

Comments/Discussion: The results of the questionnaire indicate significant concerns about the understanding of and standardization of adjustment procedures for NVGs amongst the CF operational community. Correct adjustment of NVGs is a necessity for optimal effectiveness. Studies have demonstrated that the method used for adjusting NVGs determines the level of visual acuity (VA) achieved (DeVilbiss et al, 1994; Manton 1996). The results of these studies showed significant improvement when NVGs are adjusted in an eye lane using a chart of specific contrast value under a standard illumination level (generally that of a quarter moon). Further studies demonstrated better VAs were achieved using a Snellen (letter) chart, when compared with a grid pattern (Silberman et al, 1994).

Readjustment of the objective setting prior to take-off and in-flight is appropriate as one needs to focus the NVG to infinity to be able to see far objects clearly (Verona and Rash, 1989). However, the primary adjustment must be done using a standard method to obtain optimal in-flight performance. Re-adjustment of the diopter setting of the NVG on an object of unknown size, unknown contrast, and under non-standard illumination will cause a pilot to over or under compensate the adjustment required and will result in a degradation of achievable VA (see Annex B, Figure 1). In addition to decreased VA, this will result in eye strain and fatigue. Since 75% of the NVG users in this study reported eye strain, 60% excessive fatigue, and 52% headache, it is reasonable to assume that for many, these symptoms were a result of improperly adjusted NVGs.

Once the NVGs have been adjusted to optimal performance in a standard environment and the objective has been refocused to infinity, the optimum visual acuity is achieved. Re-adjustment of the diopter setting in flight will only result in degradation of NVG performance. Visual acuity achieved with NVGs is a function of various parameters including illumination level, contrast between the object and background and technology limitations including gain, resolution and noise ratio (Levine and Rash, 1989). NVG VA will vary through the mission as a result in fluctuation of environmental parameters. Kotulak and Rash (1992) have demonstrated variation in VA with various illuminance levels and object contrast (see Annex B, Figures 2 and 3). From their experimental data, the best visual acuity achievable for a high contrast target under full moon illumination was 20/35, but this degraded to 20/80 under overcast conditions. Results for medium contrast under the same conditions varied from 20/60 to 20/300. Under low contrast, target resolution went from 20/120 to being undetectable even under clear starlight. VA does not remain constant with varying terrain and illumination, and re-adjustment of the diopter setting with changes in weather or illumination is counter-productive.

Optical alignment of NVGs was mainly related to the lack of vertical and eye relief adjustment range provided on the AN/AVS-501 goggles. This problem has been studied previously by Kotulak (1992) who showed that not achieving the required eye relief distance would cause a diminution in the field of view (FOV). In fact, the 40° FOV was rarely achieved with the ANVIS-AN/AVS-501. However, he was able to demonstrate that an increase of 7mm in the eye relief range would solve this problem. It is believed that this correction was introduced with the new NVG generation e.g. ANVIS 4949.

(5) In-flight incidents/accidents

Only 14 (8%) of the NVG respondents reported having had an in-flight incident related to NVG use. These were divided amongst four categories – illumination, spatial disorientation, marginal weather, and perceptual problems. Table 1 in Annex A provides a brief description of each incident.

There were 43% of pilots who reported having experienced at least one NVG malfunction during flight. The most common problem was a battery malfunction (53%). Table 12 lists the number of cases reported for each NVG snag. The vast majority (93%) were corrected in flight.

Comments/Discussion: The number and variety of flight incidents reported in this survey (14 for 185 pilots) is lower than that reported in a similar study done by the US Army (Crowley, 1991). However the conditions under which the incidents occur were similar to that of the US Army report. The results from Crowley's survey present an extensive view of flight anecdotes which could be presented to CF pilots during aeromedical briefings. The categories of incidents reported are listed in Table 2 in Annex A.

The hardware-related incidents reported are also consistent with Crowley's report (Crowley, 1991). Battery malfunctions, detachment of the NVG from the mounting mechanism are common. However the US report also revealed other problems such as fogging up of the NVGs and differences in brightness between tubes, not reported in this survey.

(6) Use of protective visual devices under NVGs

Only 6% of pilots flying with NVGs who did not wear corrective spectacles reported wearing protective spectacles under their NVGs. The reasons given include fear of further degradation of VA or FOV (50%), and concern about introducing visual distortion (38%). Only 3 pilots wearing protective spectacles under their NVGs indicated that the lenses were anti-ballistic. The remaining 8 pilots did not provide information as to the type of protective eyewear they used under their NVGs.

Of the 24 pilots wearing corrective spectacles under NVGs, 10 indicated their spectacles were certified anti-ballistic, while 14 did not know if their spectacles met anti-ballistic criteria.

Comments/Discussion: Protective eyewear reduces the risk of potential eye injuries resulting from the disconnecting of the equipment from the mount, and from an eye safety perspective, the use of anti-ballistic eyewear should be mandatory. At the time of the survey, there was no CF policy with respect to this issue and only 6% of pilots not requiring corrective spectacles used eye protection. Pilot concerns about reducing field of view and visual acuity are likely justified. In order to maximize the FOV, the eye relief distance must be set as close to the full aft position, ie as close to the eye as possible. Even in this position, with the AN/AVS-501 NVGs, the best FOV in an operationsl setting was measured at 36-37.8 degrees, a bit short of the manufacturers claim of 40 degrees (Kotulak, 1992; Osterlund et al, 1991). However, in order to mininize the risk for serious eye injury with NVGs, the use of protective spectacles is strongly recommended.

RECOMMENDATIONS

A. GENERAL

To address the various issues that have come to light as a result of the Canadian Forces Air Operations Vision Survey, it is recommended that the Chief of the Air Staff and Commander of 1 CAD initiate a Working Group on Aircrew Vision. The Working Group should include representatives from the operational pilot community, CF Flight Surgeons, Defence Scientists, with input from outside consultants such as ophthalmologists and civilian vision researchers as required.

B. SUNGLASSES

1) The CF should develop new policy guidelines with respect to sunglasses for CF aircrew. These guidelines should address:

a) The various operational environments in which the sunglasses will be employed. Current sunglasses for aircrew utilize a transmittance level of 10-15% (Brennan, 1979, Hamilton and

Morris 1986). In certain conditions, increasing the transmittance to 25-35% may be more optimal (Task, 1989)

b) Choice of lens material. Lenses should be anti-ballistic for optimal eye protection
c) Choice of tint. Tint should be neutral to avoid colour confusion created by coloured lenses
d) Optical characteristics. Polychromatic, gradient tint and polarized lenses should be avoided
e) Sunglasses should be fitted with the helmet or headset

2) These standards should be provided to all suppliers of CF sunglasses. The precise MILSPECs should be detailed by the Working Group on Aircrew Vision. It is recommended that the Working Group designate DCIEM/Aerospace Life Support Group as the quality control agency.

C. SUN VISORS

1) The CF should carry out an assessment of the transmittance requirements for sun glasses and sun visors in various operational environments including high altitude flights, low level flying in summer and winter, and low altitude flying over water

2) Visors whether clear or tinted should be maintained in the best possible condition to minimize the adverse effects of glare caused by scratches or pitting on the visors which reduce visual acuity particularly with respect to low contrast objects

D. LASER PROTECTIVE DEVICES (LPDs)

1) Briefings should be provided to all CF aircrew regarding the limitations and optical characterstics of all LPDs currently in use in the CF, and briefing notes should be developed and be available for each type of LPD

2) A training program should be developed for LPDs to include experience with and strategies for coping with the visual limitations inherent with coloured LPDs

3) LPDs currently used by the CF should be evaluated regarding any potential colour confusion which may result from their use in CF aircraft particularly with respect to colour displays

E. NIGHT VISION GOGGLES (NVGs)

1) Standard methods for optimal adjustment of NVGs should be developed and be made readily accessible for all aircrew using NVGs. The optimal method is adjustment in a standardized eye lane with Snellen charts and standardized luminances.

2) A training protocol should be developed for all aircrew using NVGs. Training should include:

a) In-depth briefing of NVG function including the effects of varying illumination levels, weather, varying object and background contrast, and equipment technical limitations with respect to best-obtainable visual acuity using NVGs;
b) discussion of the importance of initial standardized adjustment;
c) the adverse effects on visual acuity of improper focussing techniques, or in-flight refocussing;
d) human factors/safety issues including:
    i) the use of protective devices under NVGs
    ii) illusions related to environmental conditions, terrain features and illumination level
    iii) information from flight safety briefings/anecdotes from the CF and other NATO/ASCC countries

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Table 1 DEMOGRAPHIC DATA OF THE PILOT POPULATION WEARING SUNGLASSES FOR FLYING DUTIES

Overall population	**Percentage (%)**	
Do not wear sunglasses for flying duties	44	
Wear sunglasses for flying duties	56	
Wear CF issued	62	
Wear personal	38	
Wear prescription sunglasses	32	
Overall sunglasses	**CF issued**	**Personal**
Rotary wing (RW)	37	63
Multi-crew fixed wing (MCFW)	35	65
Single-crew fixed wing (SCFW)	52	48
Prescription Sunglasses	**CF issued**	**Personal**
Overall	62	38
Rotary wing (RW)	63	37
Multi-crew fixed wing (MCFW)	59	41
Single-crew fixed wing (SCFW)	76	24

Table 2 CHARACTERISTICS OF CF ISSUED AND PERSONAL SUNGLASSES USED FOR FLYING DUTIES

Colour	**Percentage (%)**	
	CF issued	**Personal**
Gray	45	36
Brown	11	13
Green	36	34
Amber	4	8
Blue	4	3
Smoky pink	0	6
Optical characteristics of lenses	**CF issued**	**Personal**
Polarized	23	77
Commercial blue blockers	43	57
Gradient tint	14	86
Polychromatic	27	73

Table 3

FREQUENCY DISTRIBUTION OF VISORS USED BY CF PILOTS BY AIRCRAFT TYPE

Colour	Percentage (%) Overall	Rotary wing	Fixed Wing Single crew	Fixed Wing Multiple crew
Clear visor only	2	1	1	5
Sun visor only	10	12	9	9
Clear and sun visors	68	86	88	28
No visor	20	<1	2	58

Table 4

REASONS PROVIDED FOR NOT WEARING THE CF CLEAR VISOR FOR NIGHT OPERATIONS

Reason		Frequency (count)
Induce glare		98
Seem to decrease visual acuity		95
Seem to decrease contrast		85
Induce distortion		55
Others		63
Unavailable	14	
Interference with NVGs	13	
Emergency use, special circumstances	13	
Not required for transport pilots	7	
Fogging	6	
Additional weight to helmet	3	
Incompatible with spectacles	2	
Not required wear spectacles	2	
Disorienting	1	
Too much trouble to change	1	
Other visor is LPD	1	

Table 5 OPERATIONAL USE OF VISORS BY CF PILOTS

Visor	Frequency (%)				
	Total	RW	FWSC	FWMC	Unknown
Clear					
Day without sunglasses	492	43	36	12	9
Day with sunglasses	73	47	14	33	6
Night	31	29	29	19	23
Sun					
Flat light	293	40	41	11	8
Day without sunglasses	137	44	37	12	7
Day with sunglasses	135	51	25	12	12

Table 6 PILOTS WITH NVG EXPERIENCE BY OPERATIONAL ROLES

Operational roles	Number of pilots
Overall pilots with NVG experience	185
Tactical Helicopter (TH)	132
Search & Rescue Rotary Wing (S&RRW)	15
Maritime Patrol Rotary Wing (MPRW)	5
Maritime Patrol Fixed Wing (MPFW)	0
Transport (TPT)	4
Fighter (FGT)	5
Jet Trainer (JTR)	3
Primary Trainer Rotary Wing (PTRW)	4
Unknown	17

Table 7 PERSONNEL PROVIDING NVG INSTRUCTION TO CF PILOTS

Instructors	Students (Counts)
NVG qualified instructor pilot	172
Aeromedical technician	30
Flight surgeon	30
Bioscience officer (DCIEM)	8
Line pilot	3
Company representative	1
Communications/Radar Systems Tech	1

Table 8 OVERVIEW OF TOPICS COVERED BY NVG INSTRUCTION

Topic	Frequency (Count)
NVG flying	163
Operational limitations of the NVGs	161
NVG adjustment **without** use of an eye lane	155
Prevention of visual fatigue and problems	153
Illuminance effect on NVG image	150
NVG adjustment **with** use of eye lane	131
Human factors aspects of NVG flying	130
NVG demo on mock-up board	101
NVG mountain flying	1
Installation, maintenance ,cleaning	1
Regulation of NVG flying	1

Table 9 SYMPTOMS REPORTED AFTER FLYING NVG MISSIONS

Method	Percentage of pilots reporting
Eye strain	75
Excessive fatigue	60
Headaches	52
Nausea	8

Table 10 METHODS USED FOR FOCUSING NVG'S PRIOR TO FLYING

Method	Percentage of pilots who are using this method
Focus on distant static aircraft or vehicle	52
Focus on distant buildings	44
Focus on artificial light source	35
Focus on fences or trellis	29
Focus on stars	20
Trees	6
Use 20/20 test set (S&R pilots only)	4
Eye chart in aircraft	2
Lettering on building at more than 25'	0.7
Distant geographic features	0.7
Whatever is available	0.7
Any medium size object 30-60 ft away	0.7

Table 11 NVG RE-ADJUSTMENTS MADE IN FLIGHT: TIMING AND REASONS

	Frequency (%)
Time in the mission when readjustment are made	
Right after take-off	23
Within 30 minutes of take-off	14
After 1 hr of take-off	28
Varies depending on the mission	35
	Frequency (Count)
Reasons for readjustment	
Ascent to higher altitude	19
Other*	17
Confined areas	14
Nap-Of-The-Earth (NOE) flying	10
Descent for landing	9
***Other**	
Target identification run	3
When focus become blurry	2
When there is a change in illumination	3
As required	4
Low ambient light	1
When weather is degrading	1
Function of various pairs of NVGs	1
During approaches o building	1
When taking off from lite runways	1

Table 12 FREQUENCY OF NVG MALFUNCTIONS IN FLIGHT

Problem	Number of cases reported
Battery malfunction	69
NVG snapped out of attachment/faulty mount	27
Battery cable	17
Eye tube failure	10
Electrical problems	4
Switched off due to the position of the switch/collar problems	2
Battery pack opened - not closed properly	1

Annex A

Table 1 IN FLIGHT INCIDENTS RELATED TO NVG OPERATIONAL LIMITATIONS

Depth perception problems

- Loss of all depth perception over black hole (water)
- Loss of depth perception over snow/white out conditions, had to carry out scary overshoot in snowfall

Spatial Disorientation

- Unreported physiological incident - experienced severe spatial disorientation as non-flying pilot during confined area recce on below 1.5 millilux night, tumbling sensation lasted approximately 10 seconds

Weather related problems

- Easy to get into marginal/instrument (IMC) with NVG's
- Weather caused co pilot to become disoriented and unable to perform duties
- Did not pick up deteriorating weather went IMC

Perceptual problems

- Bad peripheral vision, I did not heard the other pilot transferring control, the helicopter found itself descending while we were flying 50" from tree tops
- NOE flying - wire strike near miss - saw the actual wires (of large power lines) at about 100m, posts were hidden by trees on river banks
- Excessive video noise due to low illumination which resulted in an excessive derive close to obstacles
- Overcast night in desert (visibility 3-6 miles). Totally lost because ground did not have enough texture. De-goggled and navigated without goggles as vehicle tracks showed up as slightly lighter ground to unaided eye. Flying pilot stayed on goggles for obstacle avoidance
- Shadows caused by moon or bright cultural lights

Technical problems

- NVG shut down due to bright white light - unaided aircraft landing light

Annex A

Table 2 LIST OF NVG IN IN-FLIGHT INCIDENTS REPORTED BY CROWLEY (1992)

Degraded visual cues
- Degraded resolution/insufficient details
- Loss of visual contact with the horizon*
- Impaired depth perception*
- Decreased field of view
- Inadvertent insturment conditions (IMC)*
- Shadow effect on performance *

Reports of static illusions
- Faulty height judgement
- Trouble with lights
  - build up areas *
  - light source identification errors
  - miscellaneous effect
- Faulty clearance judgement
- Faulty slope estimation
- Faulty altitude judgement

Reports of dynamic illusions
- Undetected aircraft drift *
- Illusory aircraft drift
- Disorientation *
- Faulty closure judgement
- White out/brownout *
- No sensation of movement
- Faulty airspeed judgement
- Illusory rearward flight
- Illusion of pitch
- Sensation of stars falling
- Illusory sideward flight

Miscellaneous reports
- Crew co-ordination problems *
- Distortion

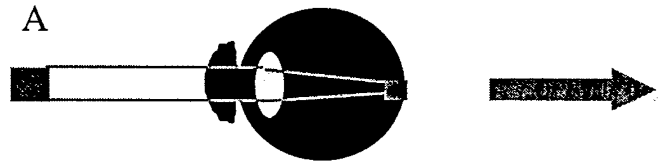
• indicate incidents also reported by CF pilots

Annex B

Figure 1

EYE STRAIN AND DIOPTER SETTING ADJUSTMENT

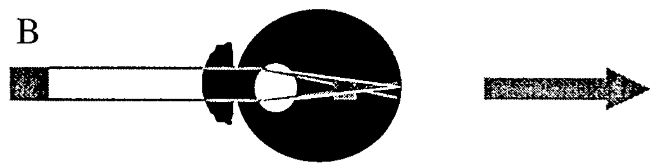
A



Accurate diopter adjustment matching the eye diopter

Optimal setting

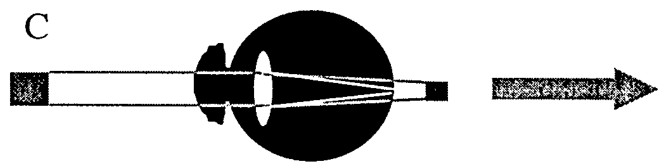
B



Diopter adjustment too strong, the lens is forced to focus the image on the retina

Too much + diopter lens

C



Diopter adjustment too weak, the lens is forced to bring back the image onto the retina

Too much - diopter lens

In the case of B and C, the lens will be able to compensate for but a short period of time to bring the image into focus onto the retina after which the image will regain its normal position and become blurry.

Figure 2 VISUAL ACUITY AS A FUNCTION OF TARGET CONTRAST AND SKY ILLUMINATION

From Kotulak and Rash, 1992

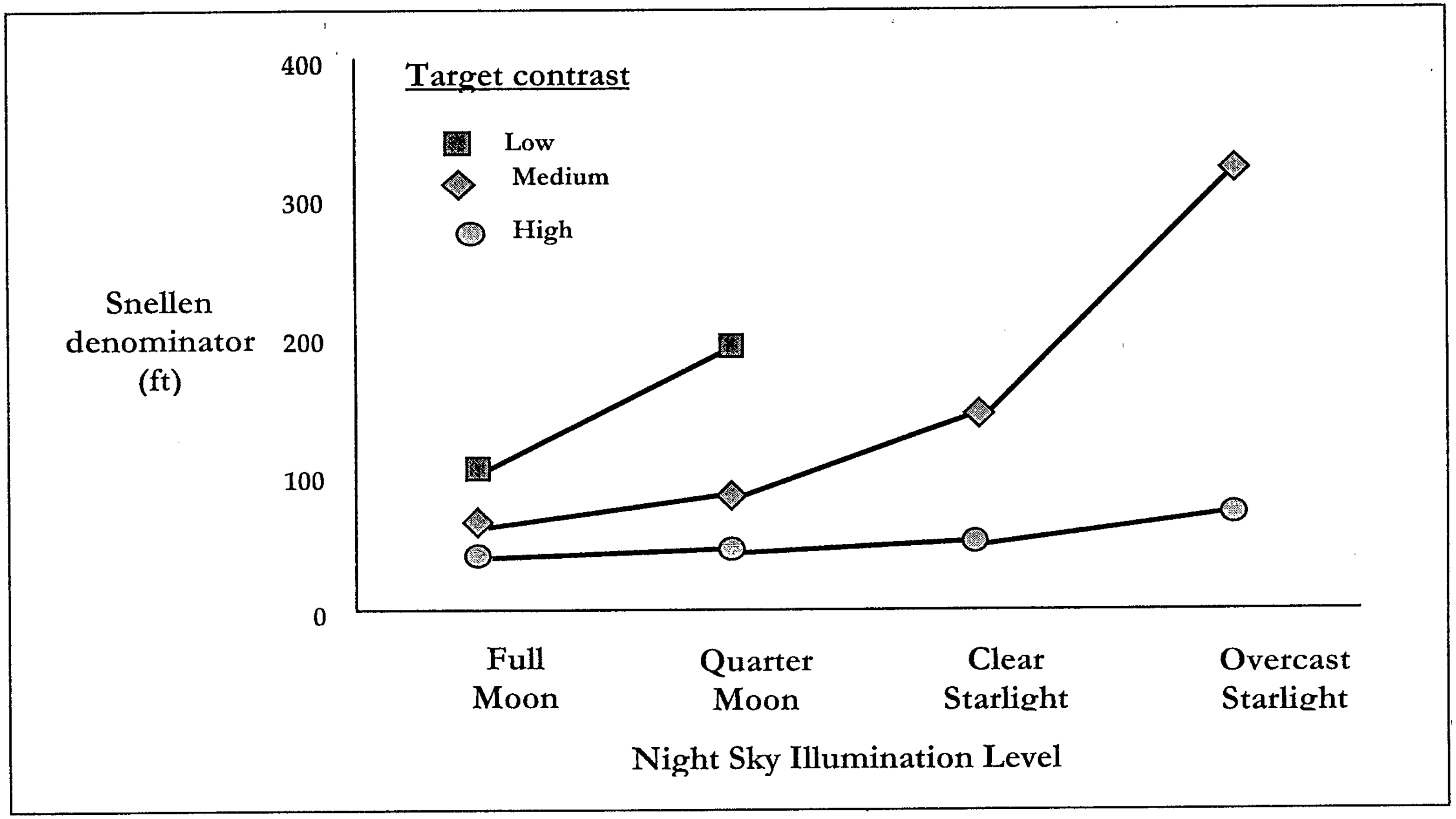


Figure 3 MATHEMATICALLY-DERIVED PREDICTIONS FOR DISTANCE DETECTION OF 6-INCH BRANCHES AT 98% AND 12% CONTRAST VALUE

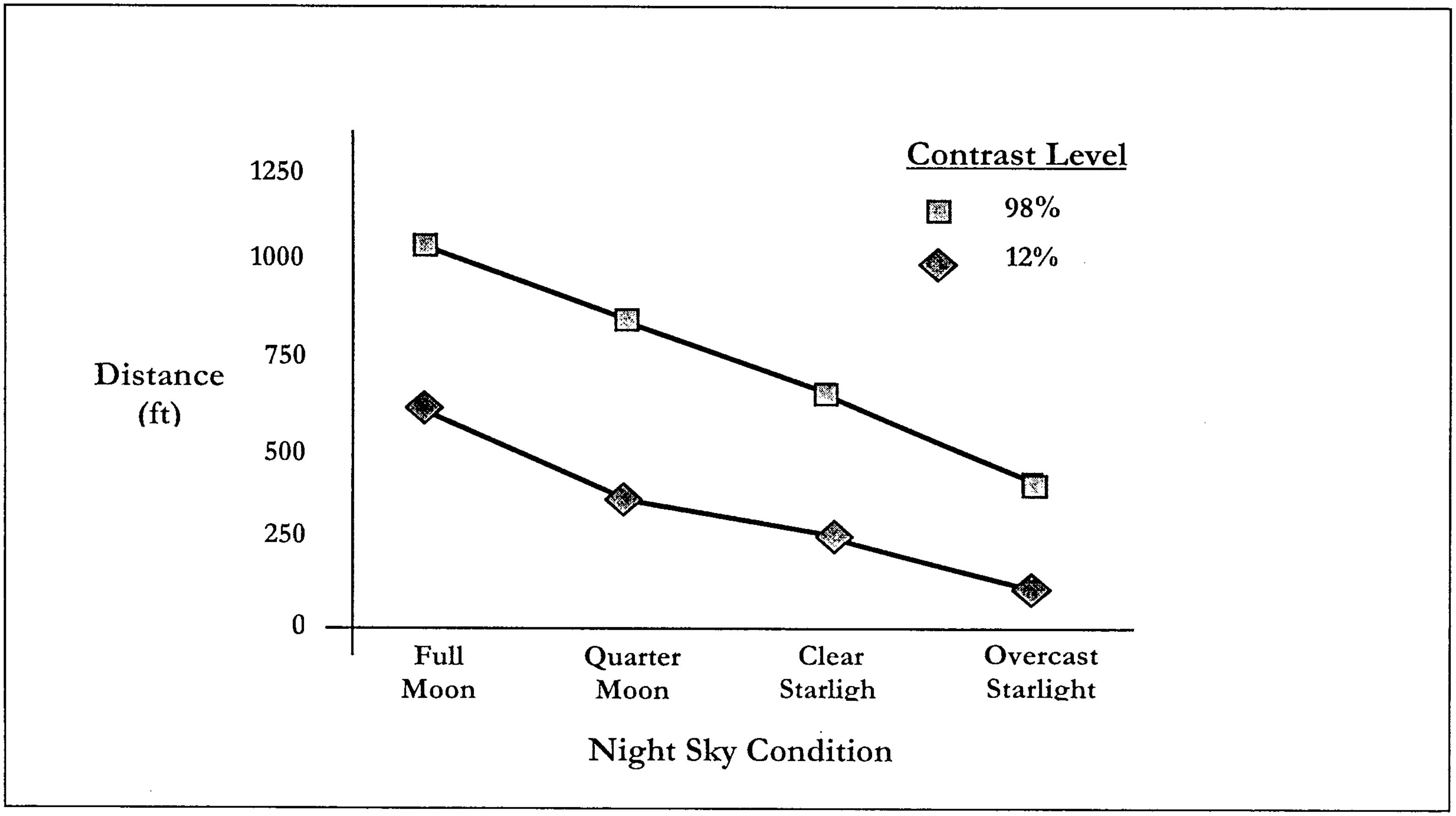
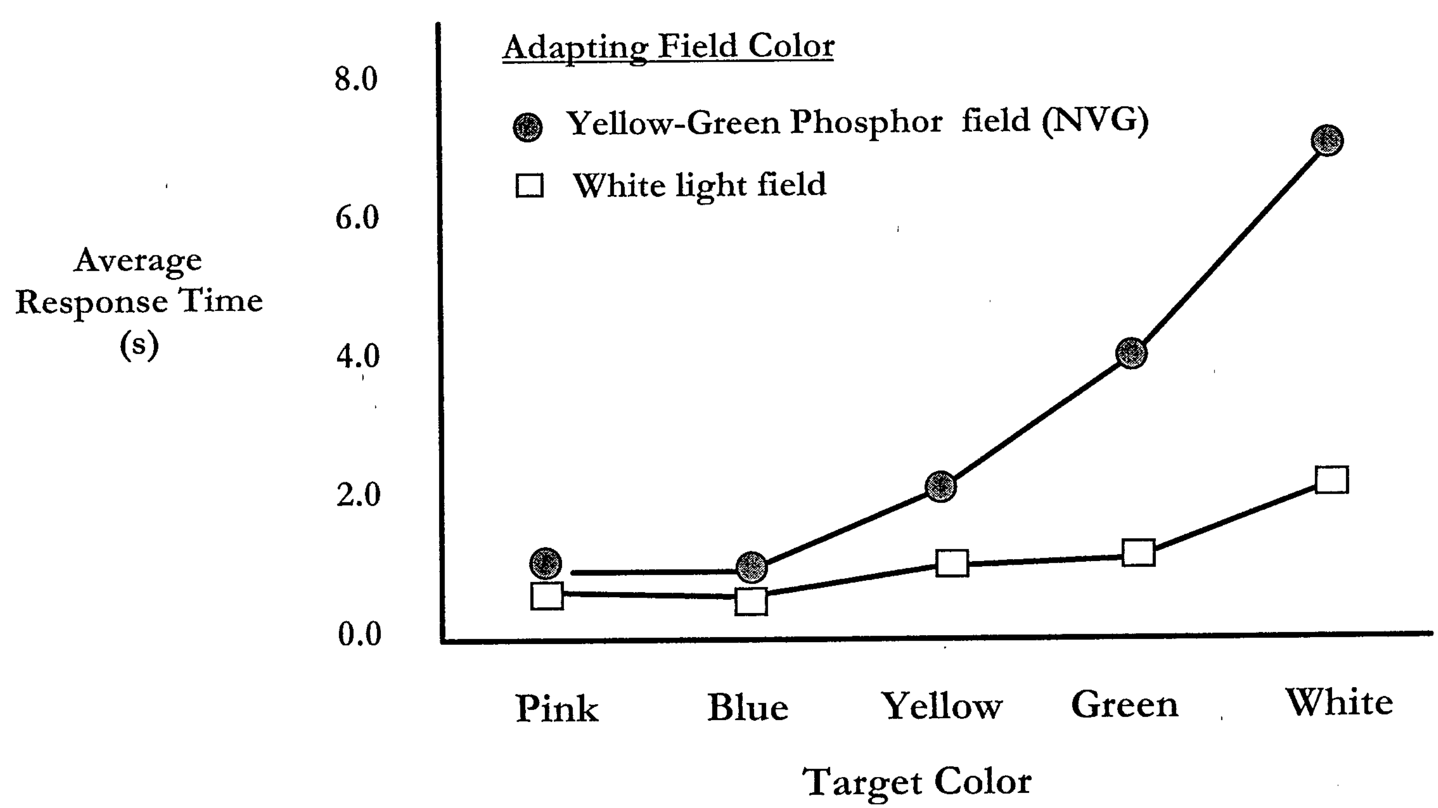


Figure 4

TIME REQUIREMENT TO PERCEIVE CORRECTLY COLOUR AFTER ADAPTATION TO A YELLOW-GREEN (NVG) AND WHITE ILLUMINATED FIELD

From Moffit et al. 1988. Aviat. Space. Environ. Med.



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14. ABSTRACT

(U) Introduction: In 1997, DCIEM conducted an Operational Vision Survey of current Canadian Forces (CF) pilots. This third report deals with those aspects related to vision protective and enhancement equipment, specifically sunglasses, visors, laser protective devices, and night vision goggles. Results: 1551 questionnaires were sent out. 813 questionnaires were completed and 200 returned "undelivered" for a response rate of 60% of those actually received. Regarding the preference of specific vision protectors, significant differences were noted between Rotary Wing (RW), Single Crew Fixed Wing (SCFW) and Multiple Crew Fixed Wing (MCFW) pilots. Sunglasses were preferred by MCFW pilots, sun visors in combination with sunglasses by RW pilots, and clear visor by SCFW pilots. The tint of the current sun visor is not universally well received and is considered as either too dark or too light for specific operations. Clear visor are used at night mainly by RW and SCFW pilots but some pilots are still reluctant to use it for fear of inducing distortion and glare. Laser Protective Devices (LPDs) are used sporadically even when a laser threat may exist. Understanding of the limitations of LPDs when viewing inside and outside the cockpit is insufficient. Night Vision Goggles (NVGs) were mainly used by Tactical Helicopter (TH) pilots. The need for better training and knowledge of the visual and operational limitations of these devices was identified. Conclusions: The survey is a useful tool in outlining the distribution and characteristics of vision protectors used by CF pilots. It indicates the need to review the operational relevance of current CF sunglasses and sun visors and demonstrates problems with training and knowledge of the limitations of LPDs and NVGs. The results from the survey provide useful information on current visual aids and protectors.

15. KEYWORDS, DESCRIPTORS or IDENTIFIERS

(U) vision; aircrew; sunglasses; visors; night vision goggles; laser protection devices